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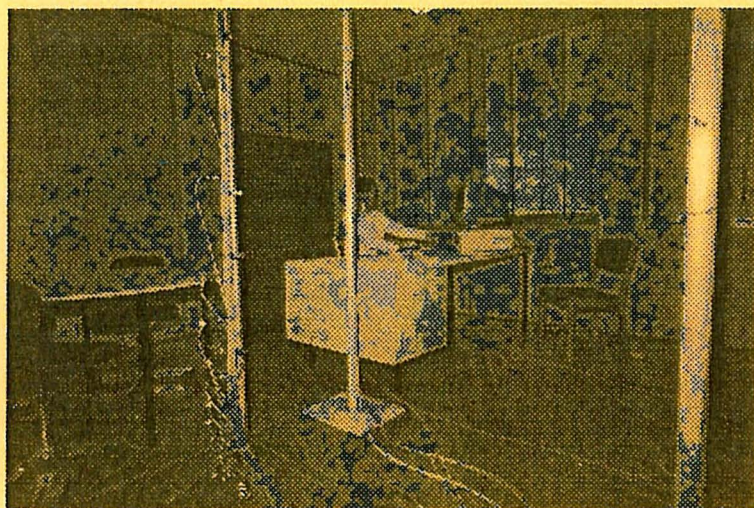
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THE USE OF TRACER GAS MEASUREMENTS IN DETECTION AND SOLUTION OF INDOOR AIR QUALITY PROBLEMS IN A DANISH TOWN HALL

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ABSTRACT

A Danish town hall with substantial complaints of poor indoor air quality is examined. This paper describes the use of tracer gas measurements which form an important part in the detection and solution of the problems. Investigations are carried out both in the field and in the laboratory using a full-scale mock-up of a typical office. Contaminant sources are simulated by means of tracer gas to examine the effectiveness of the ventilation. The exposure of a seated person is assessed by means of a breathing thermal manikin. The results show a poor ventilation effectiveness and serious thermal discomfort. A new strategy for heating and ventilation is found and tested in the laboratory and verified in the field.

INTRODUCTION

In connection with the research programme "Healthy Buildings" a Danish town hall with substantial complaints of poor indoor air quality is examined in order to investigate the cause of the problems and to find and apply a solution. In this paper the use of tracer gas measurements in the detection and the solution of the indoor air quality problems is addressed, see also (1).

A typical office in the town hall is selected for the field study and for further investigations in a full-scale mock-up in the laboratory. On the basis of the measuring results a possible solution of the problems is found regarding the heating and ventilating strategy with special emphasise on the ventilation effectiveness. Then, the solution is implemented at the town hall and one year after the first visit a new series of field measurements is performed in order to verify the solution.

METHODS

The field study is performed in the office shown in Figure 1. The office consists of three interior walls, interior floor and ceiling, and one exterior wall with three windows. In the windowsill of the central window an inlet device is located. The air is exhausted through the light fittings mounted in the ceiling. Both the heating and the supply of fresh air is provided by the ventilation system which is a dual duct system with an almost fixed air flow rate and a supply air temperature controlled by a thermostat located in the office. The supply air temperature is allowed to range from approximately 15°C to 37°C. The office is normally used by one person but with a possibility to have meetings around a small round table with up to four people taking part.

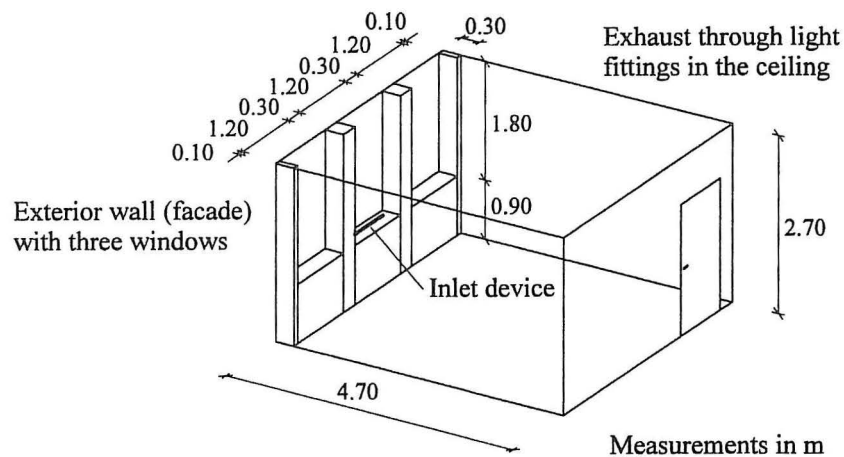


Figure 1 Geometry of the office in the town hall.

A similar room is built in the laboratory as a full-scale mock-up, see Figure 2. In order to simulate cold down-draught the windows in the mock-up consist of flat radiators supplied with chilled water in order to control the surface temperature. The mock-up is fully equipped with furniture made of chip board with a geometry and location similar to the furniture of the town hall office.

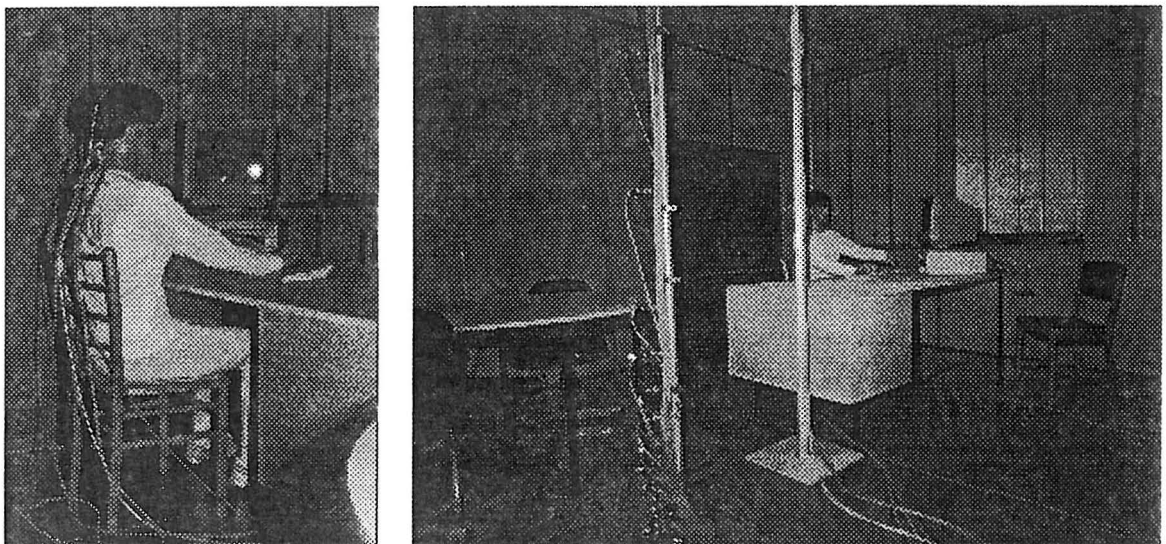


Figure 2 Mock-up of the town hall office. A person is simulated by means of the Breathing Thermal Manikin.

Surface temperatures and room air temperatures are measured with thermocouples. Velocity measurements are performed by means of temperature compensated anemometers. Tracer gas concentrations are measured by photoacoustic spectroscopy at 6 different locations with a sampling interval of approximately 1 minute.

Contaminant sources are simulated by means of the tracer gas nitrous oxide. The tracer gas is supplied through a porous foam rubber ball, \varnothing 0.1 m. Two different locations are applied.

Source 1: Location at the floor where the dense tracer gas (1.5 times heavier than the room air) is assumed to spread along the floor and simulate a planar source. *Source 2:* Location on top of a bookcase where the dense air is assumed to flow down the bookcase simulating a contaminant emission from the bookcase (or from the wall). *Source 3:* In the laboratory a third contaminant source is also applied in order to simulate a constant and evenly distributed emission from the floor. In this case the tracer gas is supplied through a perforated and branched plastic tube shaped as an H located below a perforated plastic film covering the entire floor.

In order to assess the personal exposure to the contaminant sources a Breathing Thermal Manikin (BTM) is applied in the laboratory measurements, see Figure 2. The BTM is shaped as a 1.7 m high average sized woman developed from a female display manikin wound with resistance wire. The wire is used sequentially both for the heating and for measuring and controlling the skin temperature of the manikin. The surface temperature and the heat output correspond to people in thermal comfort. The BTM has an artificial lung to simulate respiration.

Measurement procedures

The study is separated in three parts starting with a field study where the problems are detected by means of measurements and inspections. Then a full-scale mock-up is built in the laboratory for further investigations and to find a possible solution of the problem. The solution is then implemented at the town hall and a second field study is performed in order to examine the result and verify the solution.

Both field studies are performed during a week in the middle of March, the second field study one year after the first one. In both cases the outdoor temperature range between 0°C - 5°C where there is a heating demand. This procedure is chosen to obtain approximately same load on the office. During the field study a person is working at sedentary activity level in the office. People are allowed to enter and leave the office but otherwise the door is closed.

Tracer gas measurements are used to find the air change rate, the ventilation effectiveness and the age-of-air (2). The ventilation effectiveness expresses the ability of the ventilation system to remove the contaminants. The age-of-air expresses the ability of the ventilation system to supply fresh air to the office. The measurements are summarised in Table 1.

Table 1 Tracer gas measurements performed in the present study.

Measurements	Source 1	Source 2	Source 3	Age-of-air
Field study, old strategy	x	x		x
Laboratory, old strategy	x	x	x	x
Laboratory, new strategy			x	x
Field study, new strategy	x	x		x

RESULTS

In Figure 3 vertical concentration profiles measured during the two field studies are presented. Both the concentration distribution in case of source 1 and source 2 are shown for the old as well as the new heating and ventilating strategy. Concentrations are made dimensionless by dividing by the return concentration, c_R , i.e. $c^* = c/c_R$.

A possible solution is to separate the heating and the ventilating function. The heating is thus managed solely by heating panels equipped with thermostats and mounted below each of the three windows. Thus, the ventilation system is mainly used for fresh air supply. The inlet temperature is kept constant at 20°C. Another important change is a new inlet device with a better ability to create a recirculating flow in order to obtain a higher ventilation effectiveness. This solution is found to work well in the laboratory and is also confirmed by smoke visualisation and measurements in the town hall after the implementation.

The concentrations measured 0.1 m above the floor show some fluctuations and relatively high concentration levels. This is due to the location close to the contaminant source both in case of source 1 and source 3. This measuring point will mainly indicate some local phenomena close to the source and should not be used to indicate the general concentration level in the occupied zone in this case.

If the concentration at 1.1 m and 1.8 m are observed in Figure 3 a significant improvement of the ventilation effectiveness is found. After the new strategy is implemented the dimensionless concentration is close to unity indicating a condition of fully mixing. This fact is also found by means of the BTM where the personal exposure index, ϵ_e , in case of source 3 increases from 0.42 to 0.85 when the old strategy is changed into the new one (fully mixed room air corresponds to $\epsilon_e = 1$). Figure 5 shows an improvement of the local air exchange index in the heights of 1.1 m and 1.8 m in the field measurements.

The contaminant source 3 covering the entire floor is chosen as test case in the series of laboratory measurements where the new heating and ventilating strategy is chosen. This kind of contaminant source is supposed to be a potential worst-case regarding the indoor air quality. Low velocities above the floor cause high local concentration levels and the occupants may be exposed to high concentration levels due to entrainment and transport of contaminated air along the body in the convective ascending air current (3).

In general it can be stated that it is very useful to apply tracer gas measurements in order to find and apply solutions of indoor air quality problems regarding the ventilation effectiveness.

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